TECHNOLOGICAL COMPETITION IN THE PACKAGING MARKET

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SUMMARY

This paper analyses the dynamic features of the innovation process by examining technological competition in the drinks packaging market in Spain over a 20-year period. Specifically the study compares the two properties that, according to the evolutionist approach, characterise the process of dissemination and competition among alternative technologies performing one and the same function. As a result, the paper shows that in this market the process of innovation is (1) path-dependent and (2) partially irreversible.

Key words: Innovation dynamics, diffusion, path dependency, lock-in, drinks packaging market.

1. INTRODUCTION

From the publication of Richard Nelson's and Sidney Winter's seminal paper in 1982, Evolutionist Theory has exerted a notable influence on several fields of research in economics and business studies. Research on the process of technological innovation and technology management has been no exception. Papers taking an evolutionist approach by technology historians and economists of technological change (Arthur, 1989; David, 1985; Dosi, 1982, 1988; Foray, 1992; Hall, 1994; Metcalfe, 1989; Sahal, 1985) have helped decisively to enrich our understanding of the nature of the innovation process.

The evolutionist approach presents a dynamic view of the innovation process and recognises the key role of economic agents (firms and entrepreneurs) in guiding it. The approach is closely linked to, and to some extent derives from, Schumpeter's conception of economic development (Schumpeter, 1911) and is consistent with the assumptions of the resource-based approach (Barney, 1991; Peteraf, 1993; Wernerfelt, 1984).

An evolutionist approach to the study of the process of innovation enables us to examine three aspects of the process that statistical models ignore. First, when technologies are disseminated, their properties do not remain constant; rather, they evolve and compete with other technologies performing the same or a similar function. Secondly, the emergence and dissemination of innovations is the factor that historically has most affected and most often altered the institutional environment and structure of an industry. Finally, the strategic behaviour of firms adapts to the structural features of the industry and to the properties of existing technologies, but at the same time seeks actively to influence that structure and technological evolution.

It may be broadly stated that the process of innovation is determined by the coming together of three forces that follow shifting patterns of behaviour over time: (1) the evolution of the technology itself, (2) the pressure of the institutional and industrial framework, and (3) business strategies.

The evolutionist approach lays stress on the notion that firms innovate by accumulating technological knowledge and capabilities over time. The growth in volume of knowledge comes about by various learning mechanisms (R&D, by doing, by using, by failing, by imitation, etc.). But, a certain point having been reached, a key question arises: what is the nature of this process? Or, in other words, how is progress made in technological knowledge?

Until recently, research efforts have concentrated on examining the multiple *effects* of the innovation process, leaving the nature of the process itself in the background. Thus, for instance, some of the landmark papers have looked at the effects of the innovation process on economic growth, (Solow, 1957) the labour market, (Freeman *et al.,* 1982) the structure of industries, (Cohen, 1995) and company organisation (Tushman y Anderson, 1986) and strategy. (Henderson y Clark, 1990). Recently, however, some papers (Nieto, 2001, 2003b; Schilling, 1998; Teece, 1996) notably influenced by evolutionist ideas, have attempted to ascertain the nature of the process of technological innovation. These papers agree in emphasising the dynamic qualities of competition among technologies, which may be summarised in the following two points(Arthur, 1989; David, 1985; Foray, 1992):

- When technologies spread, they change and evolve. The experience built up in the use of a given technology gives rise to a range of learning processes that improve that technology, such that its performance is enhanced the more widely it extends. Dissemination/innovation is a dynamic process that causes, through various mechanisms, continuous improvement in a given technology. This feature is clearly apparent in many technologies, such as computer software and automobiles, among others.
- Every decision to adopt a given technology has a positive feedback effect, such that the likelihood of selecting that same technology in future rises. This effect means that in most cases one technology attains preponderance over the rest, and this becomes partly irreversible. Competition among technologies for the manufacture of nuclear reactors, aircraft engines and video standards constitutes a clear example of this process.

Hence the dynamic nature of the innovation/dissemination process for most technologies may be described by the following two properties:

- The process of technological innovation is path-dependent.
- The technological innovation process is partly irreversible due to the effect of feedback mechanisms (*lock-in*). These mechanisms make it very difficult to depart from a given technological trajectory when it has gained a position of dominance over the rest.

This paper discusses and examines these two dynamic properties of the process of innovation. Therefore, the next section establishes the theoretical framework of this investigation and the propositions to be tested. The third section, in order to test those propositions, examines the process of technological competition in the drinks packaging market in Spain over a 20-year period. Finally, the main conclusions are set out.

2. THE DYNAMIC PROPERTIES OF THE PROCESS OF INNOVATION

As pointed out above, the papers by Nieto (2001, 2003b), Schilling (1998) y Teece (1996) which make use of the contributions made from the evolutionist approach, (Arthur, 1989; David, 1985; Dosi, 1982, 1988; Foray, 1992) have said that the properties that make the process of innovation a dynamic one are the following: (1) it is path-dependent and (2) partly irreversible. Each of these two properties is assessed below.

2.1. The process of innovation is path-dependent

The assumption that the process of innovation is path-dependent plays a central role in the evolutionist approach, and reflects the fact that the evolution of a technology depends in fundamental ways on the trajectory that it has followed in the past. This concept can be expressed schematically in three phases (Foray, 1992): (a) at any time, the choice among different technological alternatives performing the same function is influenced by earlier choices; (b) minor historic events occurring at the outset of the process and the earliest choices made play an essential role in future evolution; (c) earlier choices determine not only the next choice but also the likelihood of selection of each given alternative.

Technological choices made in the present will influence the later learning process by deciding the future path of the innovation process (David, 1975: 4). In the context of competition between two technologies emerging simultaneously, the earliest decisions are highly important. Thus, various minor events, such as unexpected success in the development of a first prototype, order of arrival on the market, the whim of the earliest technology selectors, political circumstances, etc., may cause a technology to become widespread enough for it to become dominant (Arthur, 1987). The order in which these events, however trivial, come about will affect the dissemination of each technological alternative and influence its future development.

This scenario has been expressed in the form of various concepts commonly used in papers about innovation. It is commonplace to reflect the cumulative nature of the innovation process by representing the evolution of a *technological trajectory* (Dosi, 1982) or an *innovation avenue*. (Sahal, 1985).These technological trajectories/avenues evolve in the context of certain *technological paradigms* Dosi, 1982) or *technological regimes*. (Nelson & Winter, 1982). And these technological paradigms/regimes, in turn, establish *technological guideposts* (Sahal, 1985) or define the *dominant designs* (Abernathy & Utterback, 1978) that determine the future development of the technology. In other words, technological paradigms, technological regimes, technological guideposts and dominant designs are similar concepts, and reflect the path-dependency that decides the future progress of the innovation process along technological trajectories or avenues. Therefore, the following proposition may be put forth:

P.1 *The process of technological innovation is path-dependent*.

2.2. The process of technological innovation is partly irreversible

The development of a technology in the context of a given technological trajectory generates new knowledge through a range of feedback mechanisms that help enhance performance. The mechanisms reinforce the dominant technology to the detriment of other technological alternatives against which it competes. Hence there is an increased likelihood that that same technology will again be selected in future. The positive feedback mechanisms that make the technological innovation process partly irreversible are of several kinds (Arthur, 1987):

- *Learning by doing* arises spontaneously from doing repetitive tasks in production activities. Learning by doing takes various forms, some of which have been researched in depth, such as the learning curve effect and the experience curve effect (Abernathy & Wayne, 1974).
- *Learning by using*. When users come into contact with a new technology, there arise new, previously unseen modes of use and design improvements based on customers' experience. The potential of this form of learning is particularly evident in high-technology industries (Rosenberg, 1982).
- *Network economies.* As a technology spreads, there tend to arise externalities, known as network economies that enhance its performance. This may take either of two forms (David, 1987): (1) direct effects: through the mere fact of an increase in the number of users of a technology (e.g., e-mail), the utility of that technology for all users is enhanced; (2) indirect effects: through improvement in the supply of supplementary services (e.g., DVD).
- *Economies of scale in technology production*. The spread and mass use of a technology allows for large-scale production of the material components of that new technology (machines, installations, parts) and thus brings about a reduction in its unit cost of production.
- *Complementary technologies*. Dissemination of a technology leads to the development of new complementary techniques to ensure the proper operation and/or enhance the performance of that technology.

The combined action of these five feedback mechanisms makes the innovation process partly irreversible. The more a technology spreads, the greater the likelihood that it will continue to spread in future. The returns on adopting that technology rise due to learning, network economies, economies of scale and complementary technologies. Abandoning a technological trajectory means that those benefits must be forgone. Indeed, the evolution of technologies along given trajectories removes the possibility of competing with the old technologies that have already been dropped, even if the relative price structure varies significantly (Teece, 1996). Therefore, the following proposition may be put forth:

P2: The process of technological innovation is partly irreversible.

3. THE DYNAMICS OF THE INNOVATION PROCESS IN THE PACKAGING MARKET

In order to examine and verify the above hypotheses, this paper looks at the process of technological dissemination and competition in the drinks packaging market in Spain over a 20-year period. There are two reasons for this choice of case-study. First, because of the intense competition among the four technologies (glass, plastic, carton, and metal) that performs packaging functions. Secondly, because, as the technology that was first dominant (glass) is displaced by the new ones (plastic, carton), the outcome of the scenario appears contrary to what the theory would predict.

Table 1 show the technological shift arising in the 20-year period studied. Glass declined in market share from 74.15% in 1978 to 26.20% in 1998, while plastic and carton packaging increased their shares almost threefold, rising from 11.34% to 33.95% and from 13.06% to 31.05%, respectively. Metal packaging experienced the fastest growth rate, increasing from 1.45% in 1978 to 8.8% in 1998. In summary, over the twenty-year period the market underwent substantial change: the dominant technology, glass, was displaced by later technologies.

Table 1. Technological shift in the packaging market

	1978	1978	1988	1988	1998	1998	2009
	Litres packaged (millions)	Market share	Litres packaged (millions)	Market share	Litres packaged (millions)	Market share	Market share
Wood							6,7
Glass	6511	74.15%	5851	52.64%	3897	26.20%	8,5
Carton	1147	13.06%	2466	22.18%	4618	31.05%	37,0
Metal	128	1.45%	334	3.00%	1308	8.80%	15,8
Plastic	995	11.34%	2465	22.18%	5046	33.95%	31,9
Total	8781	100%	11,116	100%	14,869	100%	100

Source: Prepared by the authors and ANFEVI & AIMPLAS

Figure 1 shows the three dimensions describing the drinks packaging market on the three-dimensional model proposed by Ventura & Marbella (1997). The model shows the four technological alternatives (glass, plastic, carton, and metal) that compete to meet the five functions/needs relevant to drinks packagers (present, distribute, preserve, protect, contain). Packagers have been segmented into seven customer groups, by type of drink (soft drinks, wine, juices, milk, spirits, water, and beer).

3.1. The process of innovation in the packaging market is path-dependent

Figure 2 shows the progress of the market shares of the four technological alternatives over two decades. The most salient feature is that the displacement of glass, the technology accounting for 76% of the market in 1978, comes about gradually. For over a decade glass is dominant over the emerging technologies (plastic and carton), which are below the 22% level and do not outstrip glass until 1994. The pace of this process of replacement is constrained by the effect of path dependency.

Figure 1. Model of the drinks packaging market

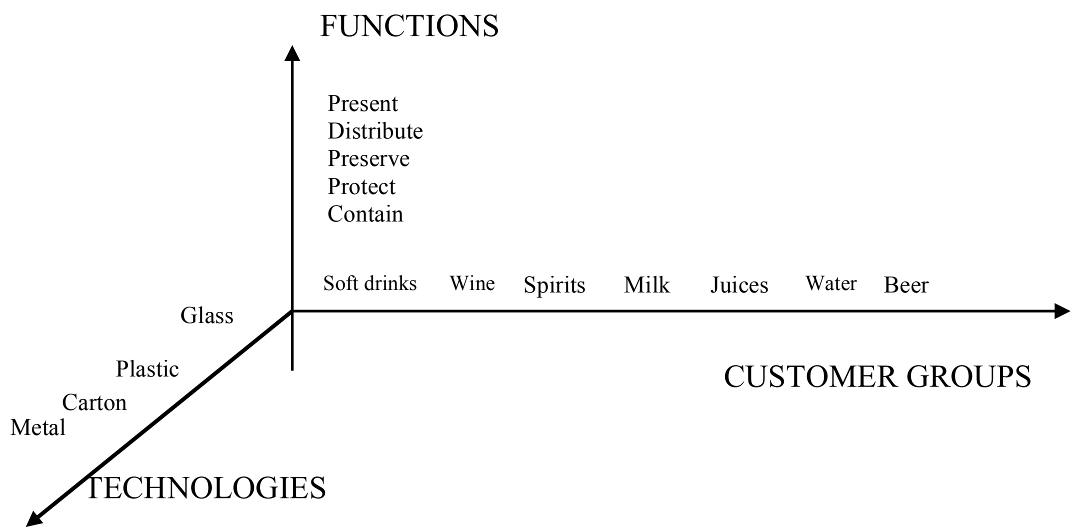
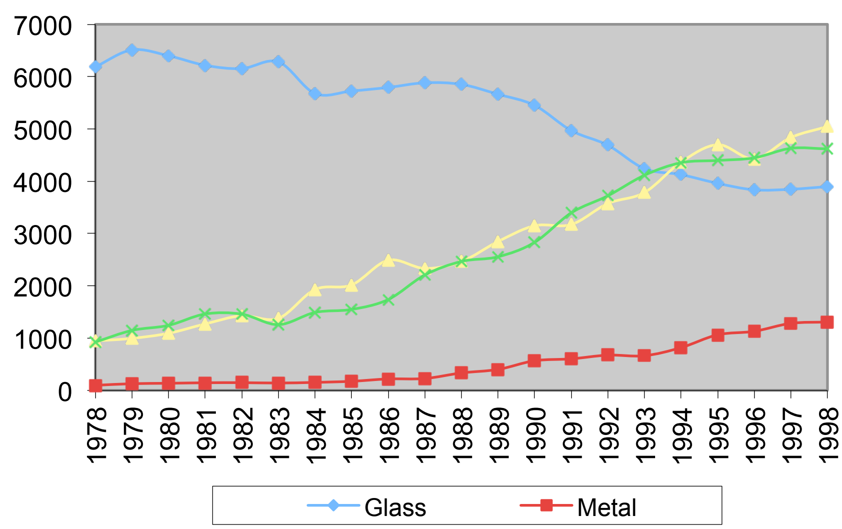


Figure 2. Progress of the market shares of the various technological alternatives in the drinks packaging market (in million of litres packaged)



Source: Prepared by the authors and ANFEVI. [32]

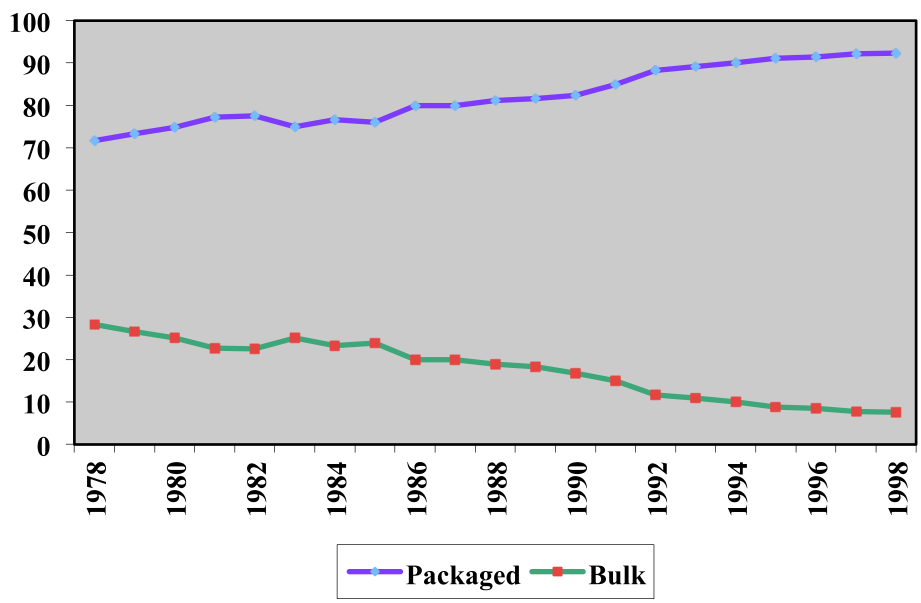
The choice made by the different customer groups (drinks packagers) among the technological alternatives is at all times influenced by earlier choices. For instance, traditional glass users, such as wine and beer bottlers, by the fact of having begun to use this technology (and made their customers used to it) are strongly predisposed not to relinquish it. The new soft-drink, water and milk packagers, on the other hand, as they are not subject to this constraint, are the first to adopt the emerging carton and plastic technologies.

In addition, minor historic events occurring at the time at which a new technology arises and the earliest choices play key roles in future developments. Hence glass, by dint of being the first technology to develop, defined packaging standards with capacities (half-litre, litre, two litres) that became established and have persisted to date. This held back and constrained the development of the new technologies, which had to adopt those dominant standards. Today, there are a great many carton and plastic packages of those specific capacities for milk, wine, soft drinks and water, thus replicating the standards first created by glass. This shows that in the period under study the technologies at issue bear out the proposition that choice of technology is influenced by earlier decisions. The earliest choices as to packaging prototypes made for glass influenced the progress and development of the new packaging technologies. Therefore, it may be asserted that carton and plastic technologies became dominant over glass once they had been brought into line with the established standards.

To explain in evolutionist terms the process of replacement described above, a further series of events should be taken into account. While these events are independent from the performance of the technologies, they nonetheless influence the process of technology dissemination by changing the competitive context. The most significant facts are:

Gradual displacement of consumption of bulk-marketed drinks by packaged drinks. This fact, which in itself is independent of the technology, favoured the dissemination of the carton technology in some segments of milk and wine packaging which were formerly marketed in bulk form (Figure 3).

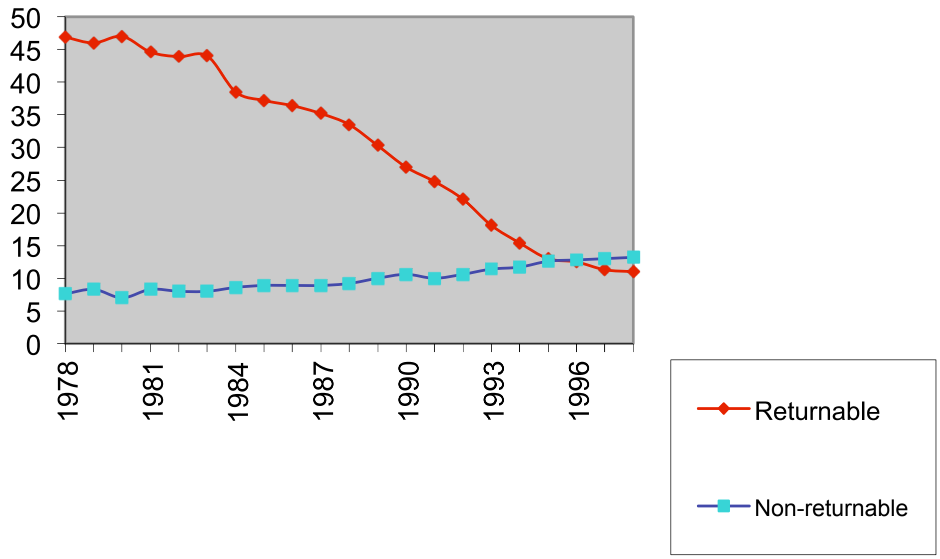
Figure 3. Development of consumption of bulk-marketed and packaged drinks



Source: Prepared by the authors and ANFEVI. [32]

Preference for disposable, one-time packages. This favoured the carton, metal and plastic technologies, because the packages made with those technologies are non-returnable and thus easier to use and more versatile. They are also not path-dependent on standardisation and are better suited to the logistics of the operating chain of some agents (large distribution facilities) that take part in the process of removal for re-use (Figure 4).

Figure 4. Development of the use of returnable and non-returnable glass



Source: Prepared by the authors and ANFEVI.[32]

The invention and introduction of an 'easy-open' system for carton and metal packages. This incremental innovation originally designed to solve the difficulty of opening carton and metal containers became a factor influencing the development of the other technologies. Thus, to counteract the effect of this innovation, in 1984 glass manufacturers developed an alternative "screw-top" stopper that made bottles easier to open and enabled the consumer to re-seal the bottle after opening. However, this system had adverse effects due to the diversity of glass vessels on the market, which entailed a need to manufacture a wide variety of screw-tops, thus raising production costs and upgrade costs (new auxiliary equipment to fit screw-tops) to bottlers implementing the screw-top system. These drawbacks prevented the success of the innovation, and the ultimate beneficiaries of the process were carton and metal packages.

The development of complementary technologies (such as refrigerators) in the home. This favoured the dissemination of emerging technologies as against glass due to the flexibility and versatility of carton and plastic packages, which are easier to store in a refrigerator.

In summary, the process of dissemination of packaging technologies has been path-dependent. The order of arrival on the market and a series of events such as the creation of capacity standards, consumption habits, the logistics of recycling and re-use, opening systems, etc. have determined the conditions of technological competition. In the first of the two decades under study, these factors favoured the dominant technology and held back the spread of the new technologies. Later, those same factors worked in aid of the reverse.

3.2. The process of innovation in the packaging market is partly irreversible

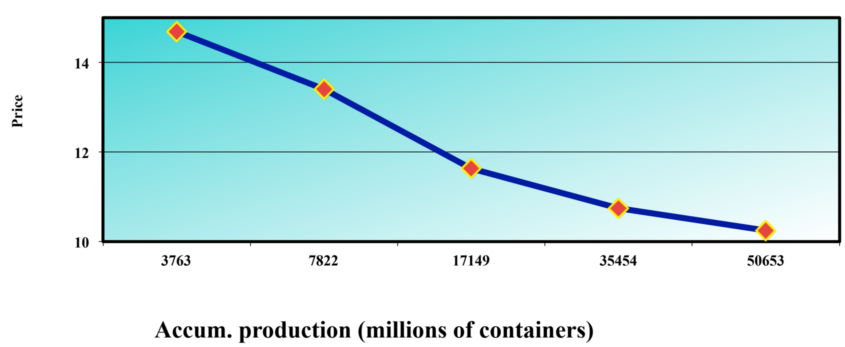
In the period under examination, the process of dissemination of the technologies competing on the packaging market involved the following feedback mechanisms:

Learning by doing. The effect of learning by doing is especially significant in two links of the value chain in the drinks packaging industry: the package manufacturer and the packager. At the former link, the effect is felt on direct costs, because this is the link where inputs are transformed into the final packaging item. At the second link, the effect is felt on indirect costs, in terms of package breakages, content losses, slow-downs and slack in equipment use, etc. These indirect costs are hard to evaluate, but nonetheless significant, because along with cost itself they influence the final package buying choice.

The experience curve constructed in Figure 5 for the glass industry shows the sharp drop in price of glass containers, which fell by 30% in the decade 1988-1998. This price reduction partly protected glass from the emerging technologies. As pointed out earlier, the new technologies had higher growth rates and, therefore, steeper experience curves, due to their being at earlier stages in the industry life-cycle.

Figure 5. Development of the price per glass container in constant 1992 $.

Linear scale



Moreover, the learning mechanism benefiting technologies other than glass is boosted by its higher specialisation, as it focuses on a lesser number of segments. This is borne out by the fact that plastic caters for only three segments (soft drinks, water and milk), metal caters for two (soft drinks and beer), and carton technology for three (wine, juices and milk). Glass, on the other hand, is present in all market segments.

Learning by using. This form of learning chiefly affects three links in the value chain of the industry: packagers, distributors and consumers.

On the basis of use, packagers have found that carton, plastic and metal technologies are more robust, generate fewer breakages in their filling chains and allow smaller content losses and less equipment down-time. All that translates into lower direct costs to packagers and lower indirect costs to package manufacturers, who are thus subject to lesser costs of compensation to packagers and of recovery of unusable items.

Distributors, particularly superstores, with use have learned about the above benefits and also that carton, metal and plastic packages, being non-returnable, cause less waiting time (for removal), and therefore occupy less physical space and require less labour and funding than returnable glass containers, which must await removal by packagers or their agents.

End-consumers, for their part, have learned about and placed value on the versatility of cartons and plastic packages in adapting more effectively to complementary home technologies such as refrigerators, freezers and domestic storage space. This learning by use has enhanced the performance of these technologies and aided their dissemination as against more standardised technologies, like glass, which are less flexible in terms of adapting to the development of complementary technologies.

The above shows that the "learning by using" mechanism plays a significant role in the competitive context of the four technologies by shifting the balance towards alternative technologies offering higher efficiency, flexibility and versatility, such as plastic and cartons.

Network economies. There is a clear indirect benefit arising from network economies in the field of carton technology. The technology was originally designed to cater for the milk packaging segment. After becoming widespread and accepted in that segment, it was applied, to similar standards of quality and capacity, to packaging lower-end wines, juices, sauces, oil, etc. Due to the increase in demand for cartons, the vendor (Tetrapak) can supply auxiliary processing equipment such as mixers, homogenisers, separators, etc. to carton users. Tetrapak customers are clearly favoured by the indirect benefits of network economies in the field of carton technology.

Another example of an indirect benefit of network economies in the sphere of the technologies under examination is provided by the introduction of Integrated Management Systems (IMS) to recover packages after use. The increase in the number of users of packages of the carton, plastic and metal technologies has allowed for the introduction of a new logistics system for selective packaging removal reduces transaction costs to packagers by commissioning removal from organisational structures operating under cooperation agreements among multiple agents (manufacturers, packagers, recyclers and government bodies), as against the option of each doing the work separately. The operation of the IMS is also an indirect benefit for users of carton, plastic and metal technologies, insofar as it mitigates environmental problems and gradually makes the relevant technologies cleaner.

Economies of scale. The industries that compete on the packaging market are capital-intensive and bear high overheads; economies of scale, therefore, are important. In the glass industry, on one hand, overheads represent about 40% of total costs, and the ratio fixed-asset investment/ turnover approaches 1 (Marbella, 1994). As an example a company typical of the glass container manufacturing industry operating at 83.57% of capacity had a structure in which overheads accounted for 39.45% of total costs and variables costs accounted for 60.55%. Productive use exceeding 10% of capacity allows for a reduction of unit costs of all production attained of 9.08%, thus moving from a total unit cost of 47.89 pesetas/kg to 43.54 pesetas/kg. This cost reduction owed to higher production in a given period highlights the impact of economies of scale.

In the drinks carton packaging industry 90% of production is covered by a single TetraPak plant. Similarly, metal container manufacturing is the preserve of three plants, two operated by American National Can S.A. and one by Crown Cork Spain. High concentration of production in a small number of plants has brought about economies of scale, thus further boosting dissemination of the packaging type.

Complementary technologies. A clear instance of complementary development that helps enhance the performance of carton technology has been, somewhat surprisingly and ironically, the development of the competing plastic technology. A weak point of cartons in their early stages was dampening of container walls on contact with the packaged liquid. The solution called for the development of an inner membrane of fine plastic. This innovation drawn from a competing technology (plastic) was the complement required to boost the performance and dissemination of the carton technology.

Metal technology, for its part, improved its performance and dissemination with the development of complementary technologies that use magnets to separate metals from other wastes in the recycling process.

4. CONCLUSIONS

The most significant feature of the process of technological innovation in the drinks packaging industry over the last 20 years is that there has been intense competition among four alternative technologies (glass, plastic, carton, metal) performing the same function. According to the theoretical framework deployed and the evidence, it may be said that this process of dissemination and competition among the different technologies was characterised by two factors:

The process was path-dependent, since at all times decisions on the adoption of a given technology were influenced by the whole sequence of earlier decisions. In this process, minor events occurring at the outset became highly significant and impacted subsequent development.

The process was partially irreversible, because at all times there was strong resistance to departing from a given technological trajectory. This was due to the effect of a range of feedback mechanisms such as: (1) learning by doing, (2) learning by using, (3) network economies, (4) complementary technologies and (5) economies of scale.

In addition, a number of reinforcement mechanisms gradually moved from the initially dominant technology to the emerging technologies. Up until 1994, these mechanisms had enabled glass to retain a preponderant position over its competitors. However, from 1994 on, the carton and plastic technologies became dominant due to successive technological innovations and changes in demand preferences. It appears that the impact of the reinforcement mechanisms shifted from glass to plastic and carton, which in the end became regarded as the most efficient alternatives for certain market sectors.

In view of this case, it may be held that reinforcement mechanisms can shift from one technology to another. Here, the emerging technologies (plastic, metal, carton) developed in such a way as to be compatible with glass in terms of standardisation and capacities, and exploited the competitive advantages of higher flexibility and suitability for users' preferences.

5. REFERENCES

Abernathy, W.J.; Utterback, J.M. (1978), "Patterns of industrial innovation", *Technology Review*, June/July, pp. 40-47.

Abernathy, W.J.; Wayne, K. (1974): "Limits of the learning curve", *Harvard Business Review*, vol. 52, nº 5, September/October, pp. 109-119.

ANFEVI (Asociación Nacional de Fabricantes de Envases de Vidrio): Memorias y Noticevi

Arrow, K. (1962), "The economic implications of learning by doing", *Review of Economic Studies*, June, pp. 155-173.

Arthur, W.B. (1987), "Competing technologies: an overview" en Dosi, G de (1987): *Technical change and economic theory,* Columbia University Press, New York, pp. 590-607.

Arthur, W.B. (1989), "Competing technologies, increasing returns and lock-in by historical events", *The Economic Journal*, vol. 99, pp. 116-131.

Barney, J.B. (1991), "Firm resources and sustained competitive advantage", *Journal of Management*, vol. 17, pp. 99-120.

Cohen, W.M. (1995), "Empirical studies of innovative activity" en *Stoneman, P. Ed. (1995): Handbook of the economics of innovation and technological change*, Blackwell, Oxford, pp. 182-264.

David, P.A. (1975), *Technical choice, innovation and economic growth*, Cambridge University Press, Cambridge, Mass.

David, P.A. (1985), "Clio and the economics of QWERTY", *American Economic Review Proceedings*, vol. 75, nº2, pp. 332-337.

David, P.A. (1987), "Some new standards for the economics of standardization" en Dasgupta. P.D.; Stoneman, P. eds (1987), *Economic theory and technology policy.* Cambridge University Press, Cambridge, Mass.

Dosi, G. (1982), "Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technological change", *Research Policy*, vol. 11, nº 3, pp. 147-162.

Dosi, G. (1988), "Sources, procedures and microeconomics effects of innovation", *Journal of Economic Literature*, vol. 26, pp. 1120-1171.

Foray, D. (1992), "Propiedades dinámicas de la difusión y efecto de irreversibilidad" en Gómez Uranga, M.; Sánchez Padrón, M.; de la Puerta, E. (1992), *El cambio tecnológico hacia el nuevo milenio*, Icaria, Barcelona, pp. 171-209.

Freeman, C.; Clark, J.; Soete, L. (1982), *Unenployment and technical innovation. A study of long waves and economic development*, Frances Pinter, Londres.

Hall, P. (1994), *Innovation economics and evolution*, Prentice Hall, Nueva York.

Henderson, R.M.; Clark, K.B. (1990), "Arquitectural innovation: the reconfiguration of existing product technologies and the failure of established firms", *Administrative Science Quarterly*, vol. 35, pp. 9-30.

Marbella Sánchez, F. (1994), "Rivalidad Competitiva en el sector del envase de vidrio", *Economía Industrial*, núm. 295, pp. 155-166.

Metcalfe, J.S. (1989), "Evolution and economic change" en Silverston, ed. (1989*): Technology and economic progress*, Macmillan, London, pp. 54-85.

Nelson, R.R.; Winter, S.G. (1982), *An evolutionary theory of economic change*, Harvard University Press, Cambridge.

Nieto Antolín, M. (2001), *Bases para el estudio del proceso de innovacion tecnológica en la empresa,* Universidad de León, León.

Nieto Antolín, M. (2003a), "From R&D management to knowledge management: an overview of studies on the innovation management", *Technological Forecasting and Social Change,* Vol. 70, pp. 135-161.

Nieto Antolín, M. (2003b), "Características dinámicas del proceso de innovación tecnológica en la empresa", *Investigaciones Europeas de Dirección y Economía de la Empresa,* Vol. 9, núm, 3, pp. 139-156.

Peteraf, M.A. (1993), "The cornerstone of competitive advantage: a resource based-wiew", *Strategic Management Journal*, vol. 14, pp. 179-191.

Rosenberg, N. (1982), *Inside the black box. Technology and economics*, Cambridge University Press, Cambridge, Mass. [vc. (1993): *Dentro de la caja negra. Tecnología y economía*, La Llar del Llibre, Barcelona].

Sahal, D. (1985), "Technological guideposts and innovation avenues", *Research Policy*, vol. 14, pp. 61-82.

Schumpeter, J.A.. (1911), *Theorie der wirtschaftlichen entwicklung.* [v.c. (1944): *Teoría del desenvolvimiento económico*, FCE, México].

Shilling, M.A. (1988), "Technological lockout: an integrative model of the economic and strategic factors driving technology success and failure", *Academy of Management Review,* vol. 23, pp. 267-284.

Solow, R.M. (1957), "Technical change and the aggregate production function", *The Review of Economics and Statistics*, vol. 39, August, pp. 312-320.

Teece, D.J. (1996), "Firm organization, industrial structure and technological innovation", *Journal of Economic Behavior and Organization*, vol. 31, pp. 193-224.

Tushman, M.L.; Anderson, P. (1986), "Technological discontinuities and organizational environments", *Administrative Science Quarterly*, vol. 31, pp. 439-465.

Ventura Victoria J.; Marbella Sanchéz, F. (1997), "An analysis of the process of packaging substitution in the drinks industry", *International Journal of Technology Management,* Vol. 13. pp 443-460.

Wernerfelt, B. (1984): "A resource based view of the firm", *Strategic Management Journal*, vol. 5, pp. 171-180.